Spatiotemporal analysis of relationship between increased clinic visits for respiratory disease and air pollution levels

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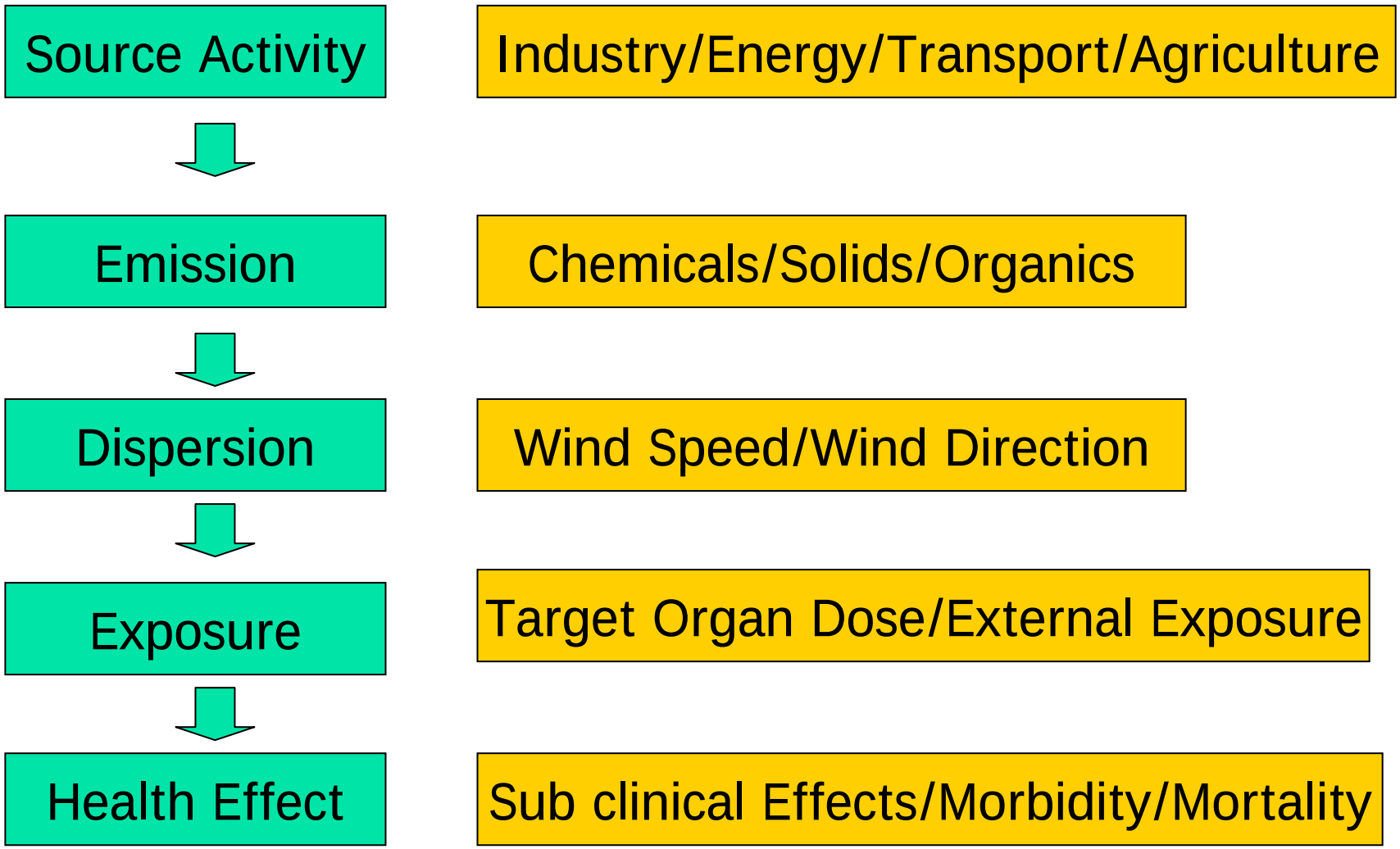
Outline

- Air pollution health studies
- The study objective
- Data descriptions
- Statistical analysis
- Main findings
- Discussion

A model of the air pollution-health chain



Exposure assessment

- Target organ dose
  - Less easy to estimate organ dose
- Personal exposure models
  - Pollutant concentration and time activities
  - Enhanced by other factors: exercise, smoking, viral infections
- Ambient air quality monitoring data
  - Less accurate

What is a health effect?

- Minor changes in respiratory function and bronchial activity
- Increases in respiratory symptom prevalence and incidence
- Acute asthma attack, exacerbations of bronchitis, wheezing, serious illness e.g. cancer, hospital admissions for diseases of the lung and the heart
- Deaths

Health effects studies

- Experimental studies
  - Gene and environmental toxicity
  - *In vitro* exposure of human or animal tissue or bacterial cultures
  - *In vivo* exposure in animals
- Controlled-chamber experiments
  - Under controlled conditions on dogs or human volunteers
  - Establish a dose-response relationship

Health effects studies

- Epidemiological studies
  - Extensive application to air pollution
    - Because of large degree of variation of air pollution levels over time and across geographic areas
  - Inexpensive database
    - Monitoring networks for regulatory objectives
    - Routinely collected mortality and morbidity statistics by government and insurance agency

Epidemiological studies

- Short-term studies (acute effect)
  - Ecological studies: examines the effects of day-to-day changes in air pollution levels on routinely measured health outcomes such as clinic/emergency room visit, mortality
  - Reflect real-life exposure conditions
  - Usually not possible to infer causality

Problems of epidemiological studies

- Time-domain methods to demonstrate associations between air pollution and various health effects in single cities.
- Two common features
  1. Mainly carried out in places with a large population.
  2. Aggregate data in a large area to represent population exposures.
- Misclassification is often compounded.

Possible solutions

- Create less heterogeneous exposures by clustering hospitals around a monitoring station as suggested by Burnett et al.
  - Exposure attribution based on clustered hospitals remains a serious challenge because some hospitals are located as far as 200 km away from any monitoring stations.

Possible solutions

- Known census clusters will provide exposure populations with smaller and more homogeneous regions (Zidek et al.).
  - Many important explanatory factors are either unmeasured or unavailable in all clusters.
  - Census areas are not equivalent to clinic catchment areas.
  - Daily outcomes in small census subdivision are sparse when the health outcome is the case for serious illness.

Possible solutions

- Cluster clinics around a monitoring station to create relatively homogeneous area of size about 20 km^2 . (Hwang and Chan, AJE 2002)

  - **Population exposure** is represented by measurements from the monitoring station.
  - **Health outcome** is daily clinic visit for minor lower respiratory illness.
  - **Two-phase modeling**: time and space

Design for this study

- Study areas: 20 small areas of townships/city districts where air quality monitoring stations situated
- Study population: sampled people in the National Health Insurance Research Database (NHIRD) who had visited clinics in the selected areas.
- Study period: 1997/01~2001/12

The data

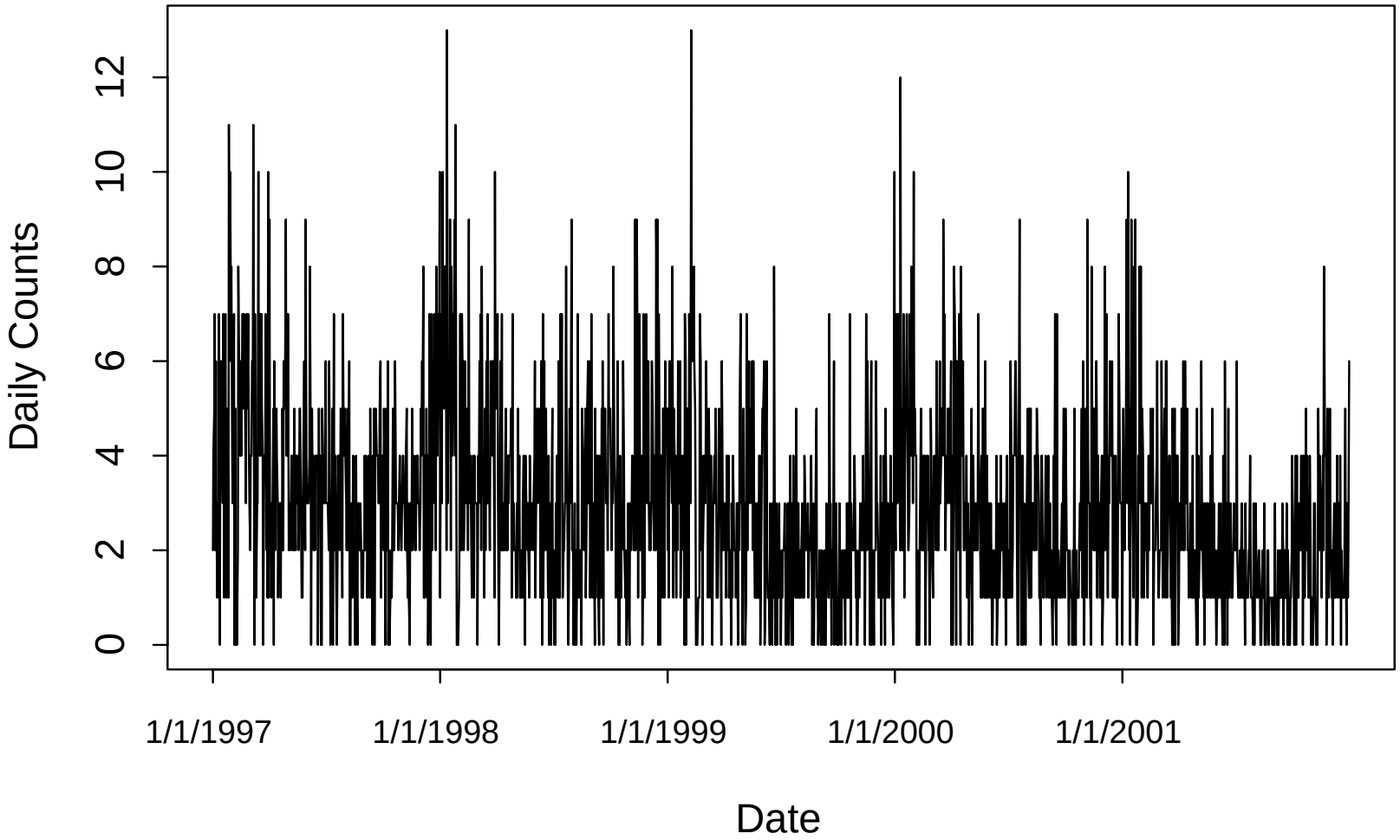
- Environmental variables from EPA
  - Daily average for NO_2, SO_2 and PM_{10}
  - Daily maximum O_3 and maximum 8-hour running average for CO
  - Daily average temperature and average dew point

The data

- Clinic visit records from NHIRD
  - Computerized clinic visit records contain clinic's ID, township names, date-of-visit, patient's ID, gender, birthday, cause-of-visit and others.
  - Five-year records from the 20 study communities in 1997-2001.
  - Clinic visits due to respiratory illness as health effects.
    - ICD-9: 464,466,480-486 and 493
    - A code: A311 and A320-A323

Daily clinic visits due to respiratory illness

基隆仁愛



Data Summary – averages over 1997-2001

Area	Popu.	Y	NO2	PM10	SO2	CO	O3	TP	DP
基隆仁愛	726	3	22.6	54.6	5.5	0.66	37.2	22.5	18.2
汐止	702	1	29.0	53.3	4.1	0.76	29.7	22.0	17.9
新店	1522	3	19.3	37.7	2.1	0.49	41.8	23.0	18.4
淡水	682	2	17.8	45.2	2.4	0.69	37.9	22.7	17.9
士林	2458	6	21.5	41.2	2.7	0.75	34.4	22.9	18.3
桃園市	3108	9	26.0	48.4	9.9	0.69	35.5	22.4	17.9
桃園大園	496	1	15.1	45.3	3.9	0.48	43.2	22.5	18.3
竹東	752	4	17.7	46.8	1.9	0.45	39.0	22.5	17.7
新竹東區	1696	6	21.8	44.7	4.6	0.60	37.9	23.3	18.1
沙鹿	1165	3	20.5	51.9	5.2	0.58	37.2	23.3	18.4
台中西區	1122	5	30.2	64.2	3.6	0.94	42.3	23.7	18.3
彰化市	2974	8	25.6	68.6	5.0	0.64	35.5	23.6	18.5
新港	132	1	17.0	74.5	3.3	0.50	48.5	23.0	18.5
嘉義西區	1180	3	26.3	78.2	4.7	0.77	42.1	23.8	19.0
新營	788	3	19.5	57.6	4.0	0.53	49.1	24.2	18.8
楠梓	916	2	25.2	74.5	5.5	0.56	50.0	24.6	19.7
前金	768	2	24.5	75.0	8.9	0.82	50.3	24.8	20.6
小港	794	2	34.0	85.8	16.1	0.90	46.6	25.3	19.7
屏東市	2193	7	19.9	76.3	4.0	0.60	52.2	24.9	19.8
花蓮市	1420	4	14.3	35.2	0.6	0.44	28.6	24.0	19.4

Statistical analysis

- Phase I: Use generalized linear mixed-effects models to model daily series of each month in the 20 areas to obtain estimated pollution coefficients on clinic visits for each month.
- Phase IIa: Average the estimated pollution coefficients across the time course.
- Phase IIb: Use Bayesian approach to combine the estimated pollution coefficients across the time course.

Phase I

- Let Y_{itms} be the clinic visit count at *t*-th day in the *m*-th month of the *s*-th year for the *i*-th area.
- For each month, fit the model

$$Y_{itms} \sim Poisson(\mu_{itms})$$

$$\log(\mu_{itms}) = (\beta_{0ms} + b_{0ms}) + (\beta_{1ms} + b_{1ms}) C_{tms} + Other$$

$$Y_{itms} \sim Poisson(\mu_{itms})$$

$$\log(\mu_{itms}) = (\beta_{0ms} + b_{0ms}) + (\beta_{1ms} + b_{1ms}) C_{tms} + Other$$

- C : current daily pollutant concentrations
- *Other* : day of week, temperature difference, dew point, area population, yearly pollution levels
- Random components $(b_{0ts}\ b_{1ts}) \sim N(0, \Sigma_{ts})$

Phase IIa

- Estimates of pollution coefficients and their standard errors are denoted by

$$\hat{\beta}_{1ts} \quad \text{and} \quad \lambda_{ts}$$

- The average

$$\tilde{\beta} = \frac{1}{60} \sum_{s=1}^{5} \sum_{t=1}^{12} \hat{\beta}_{1ts}$$

$$Var\ (\tilde{\beta}) = [Var\ (\hat{\beta}_{1ts}) + Mean\ (\lambda_{ts}^{2})] / 60$$

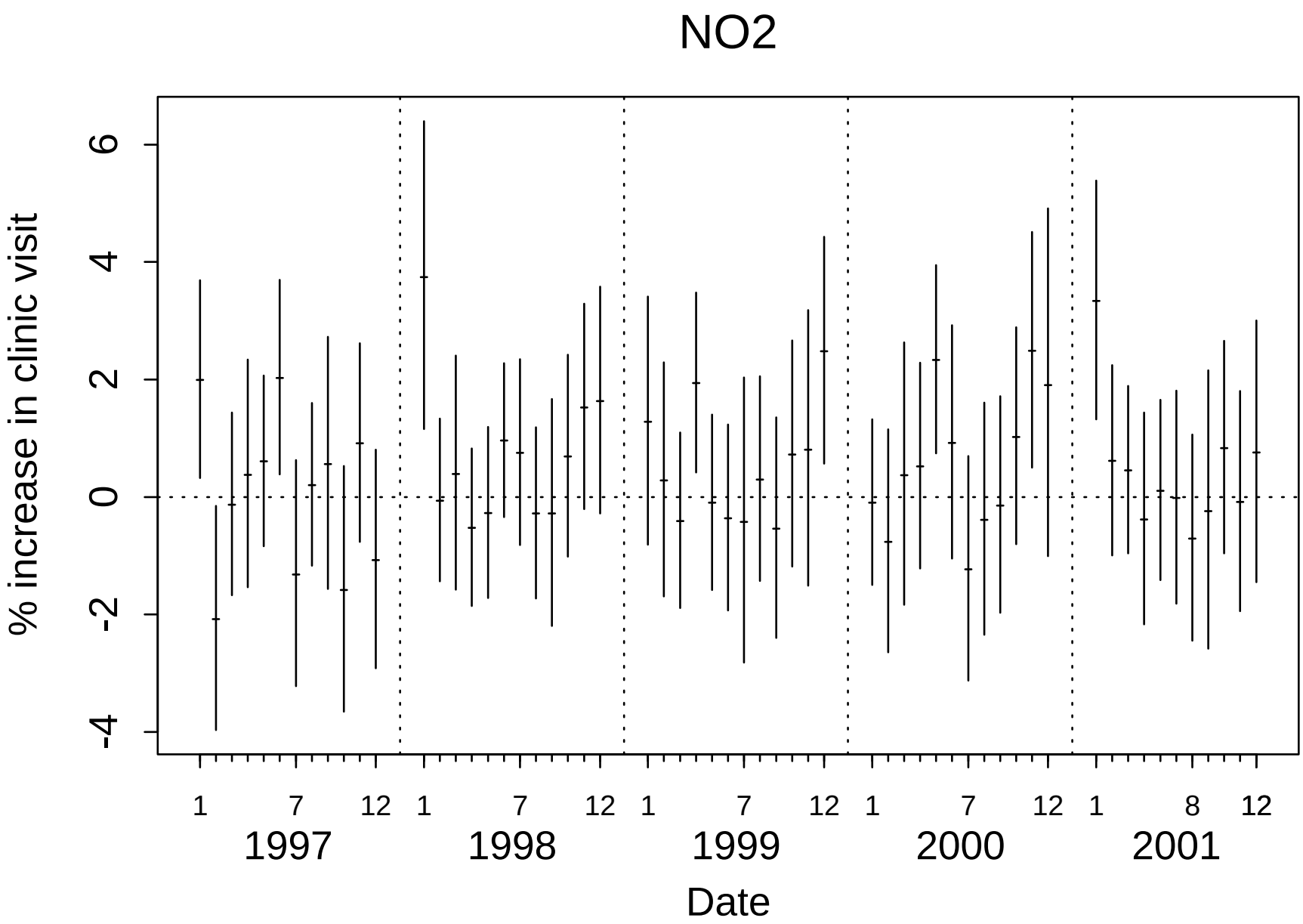
Health impact

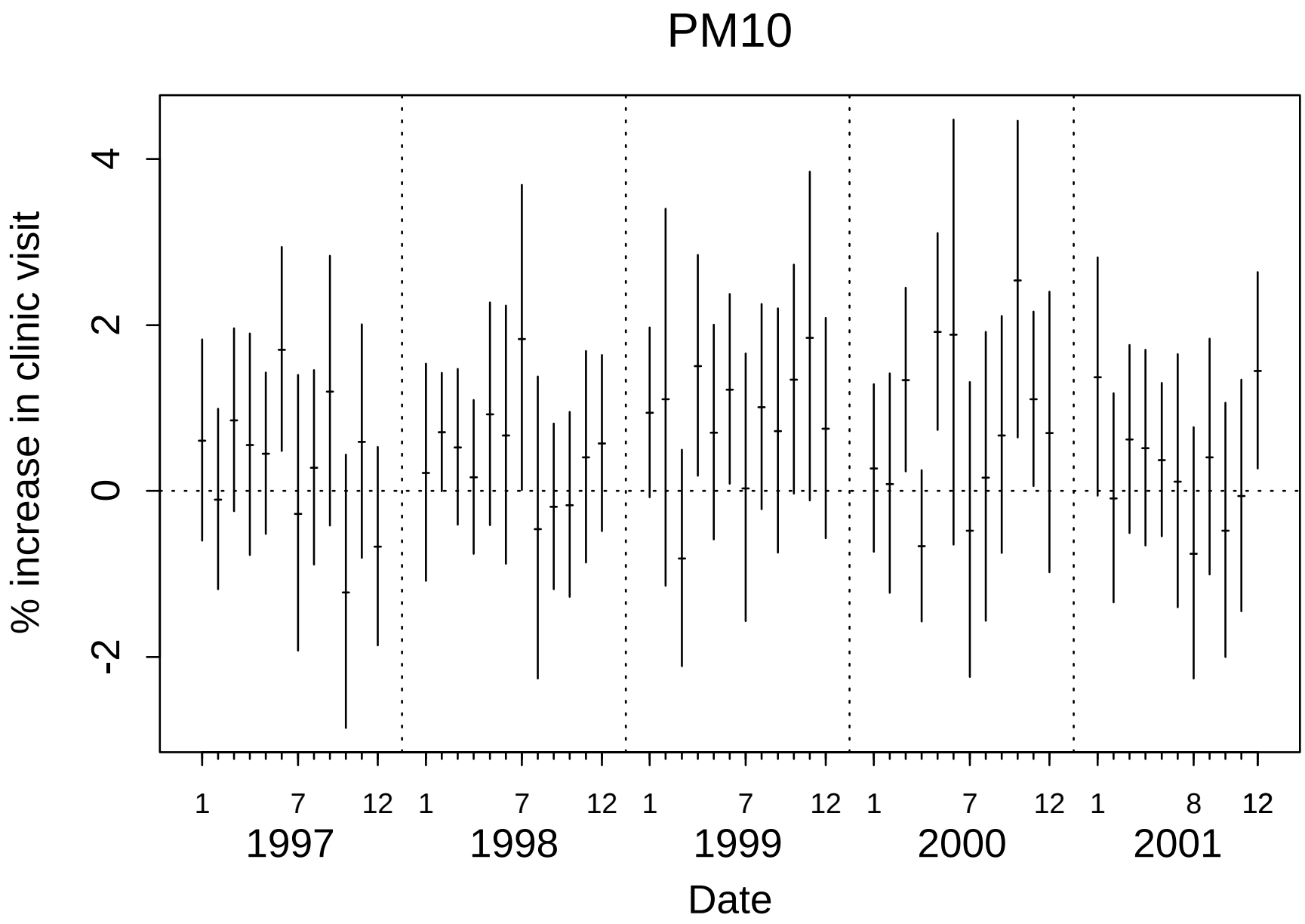
- Measured as the percentage increase in clinic visits that corresponds to a 10% increase in air pollution levels.

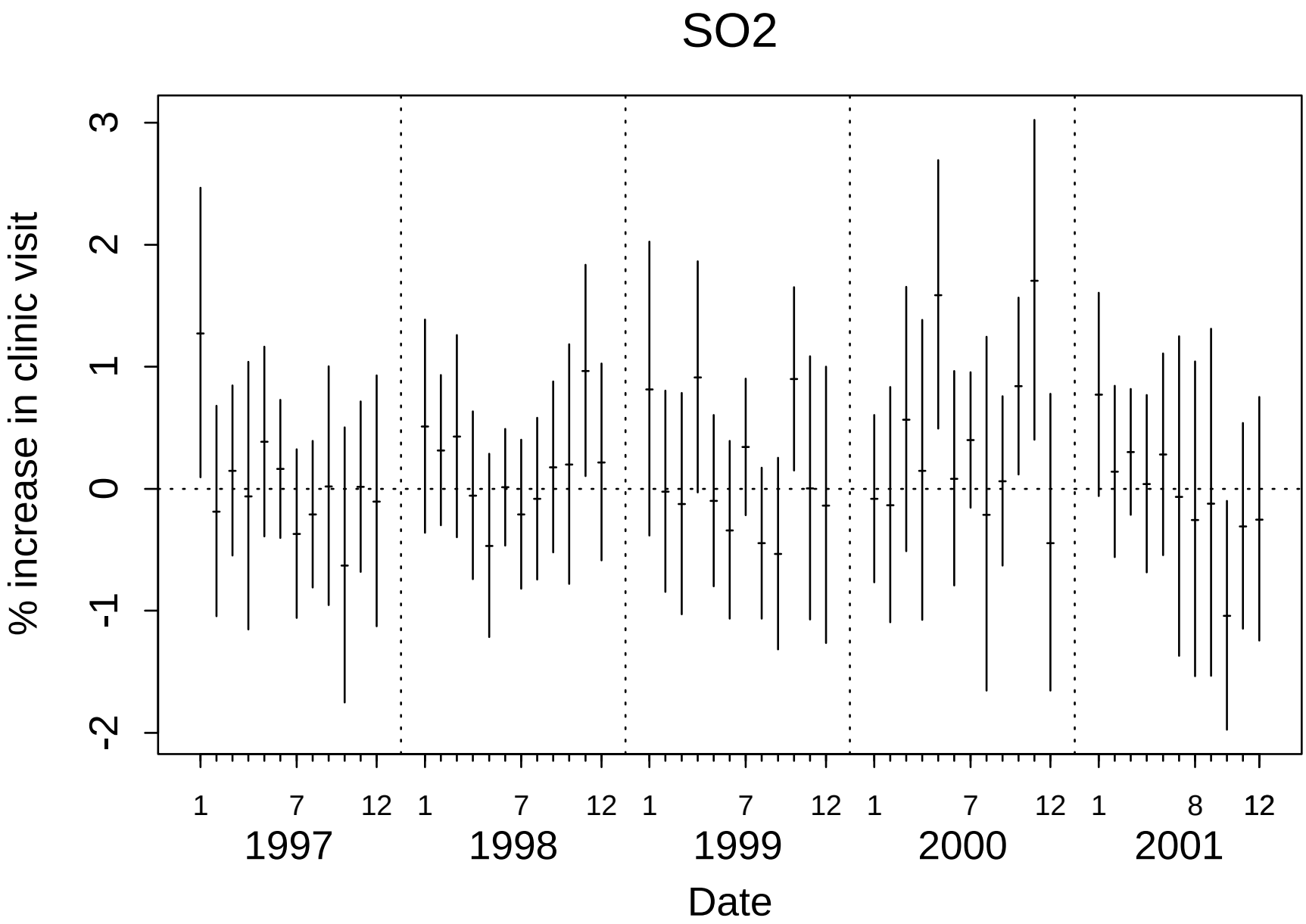
- It is expressed by $100\{\exp(0.1\times\overline{C}\times\tilde{\beta})-1\}$, where $\overline{C}$ is the corresponding overall pollution level in the 5 years.

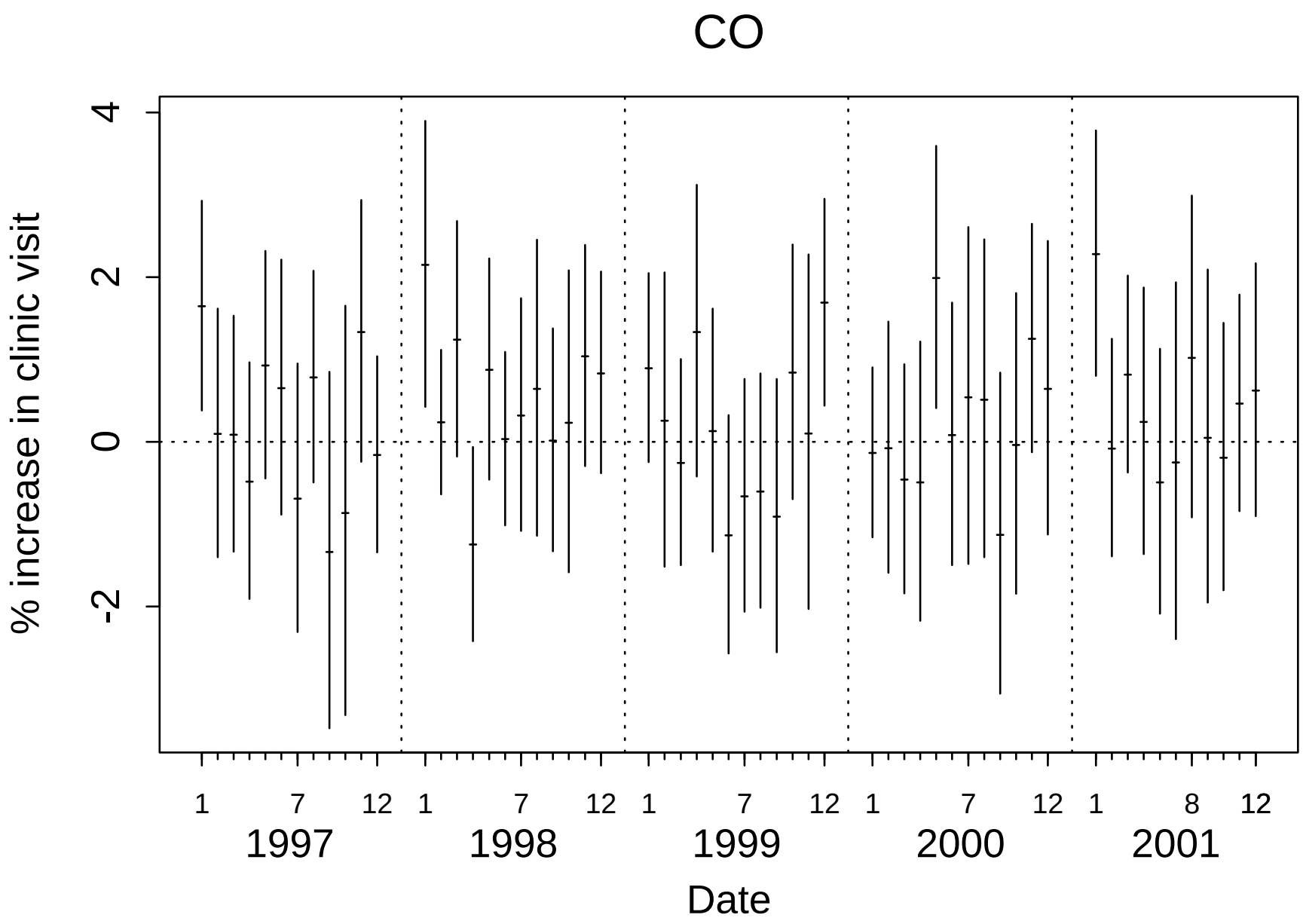
Phase I results

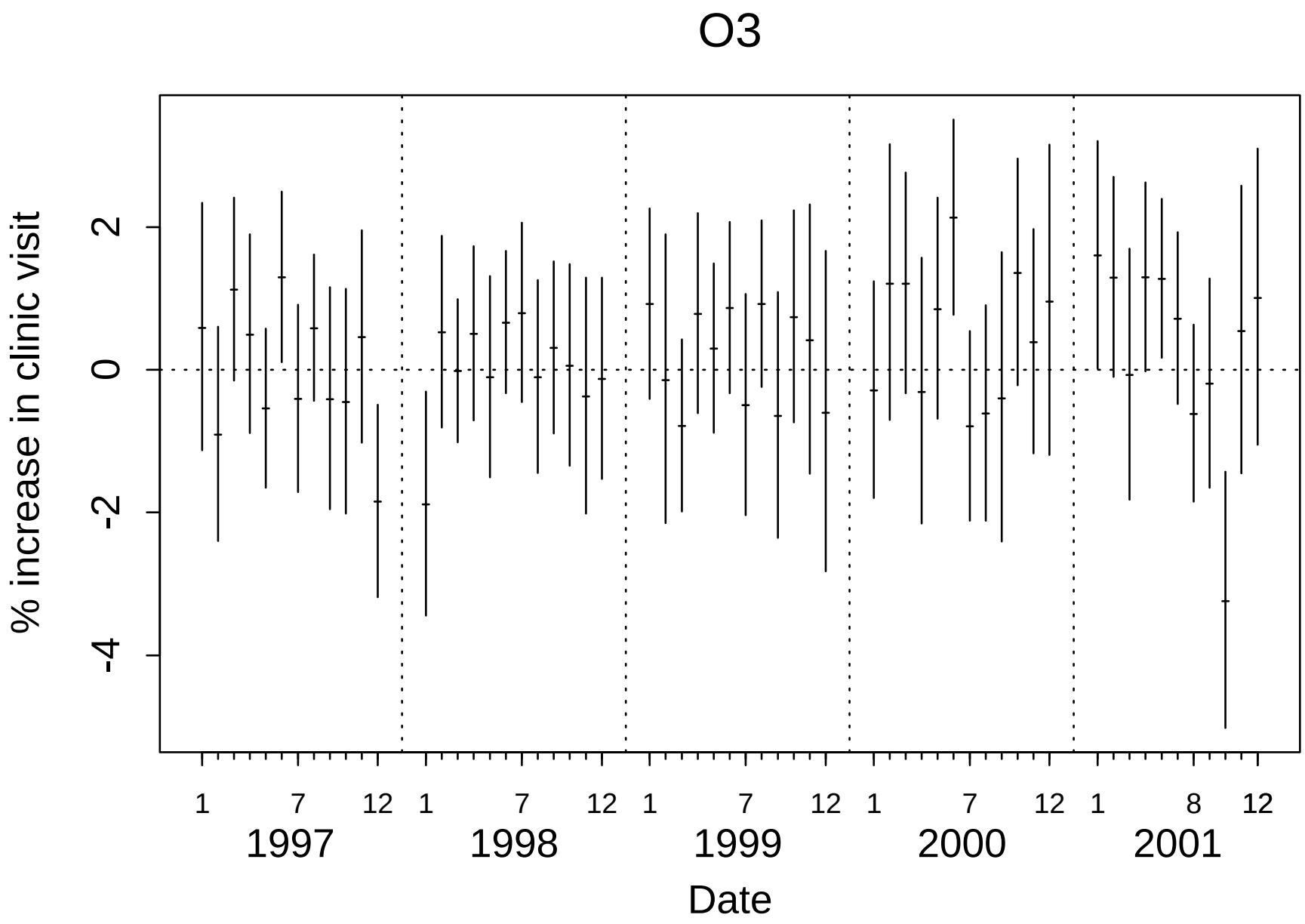
- Average per cent increased risks of clinic visits for 10% increased of average pollution levels in the 20 areas in each month


NO2
% increase in clinic visit
6
4
2
0
-2
-4
1
7
12
1997
1998
1999
2000
8
2001
Date


PM10
% increase in clinic visit
4
2
0
-2
1
7
12
1997
1998
1999
2000
2001
8
Date

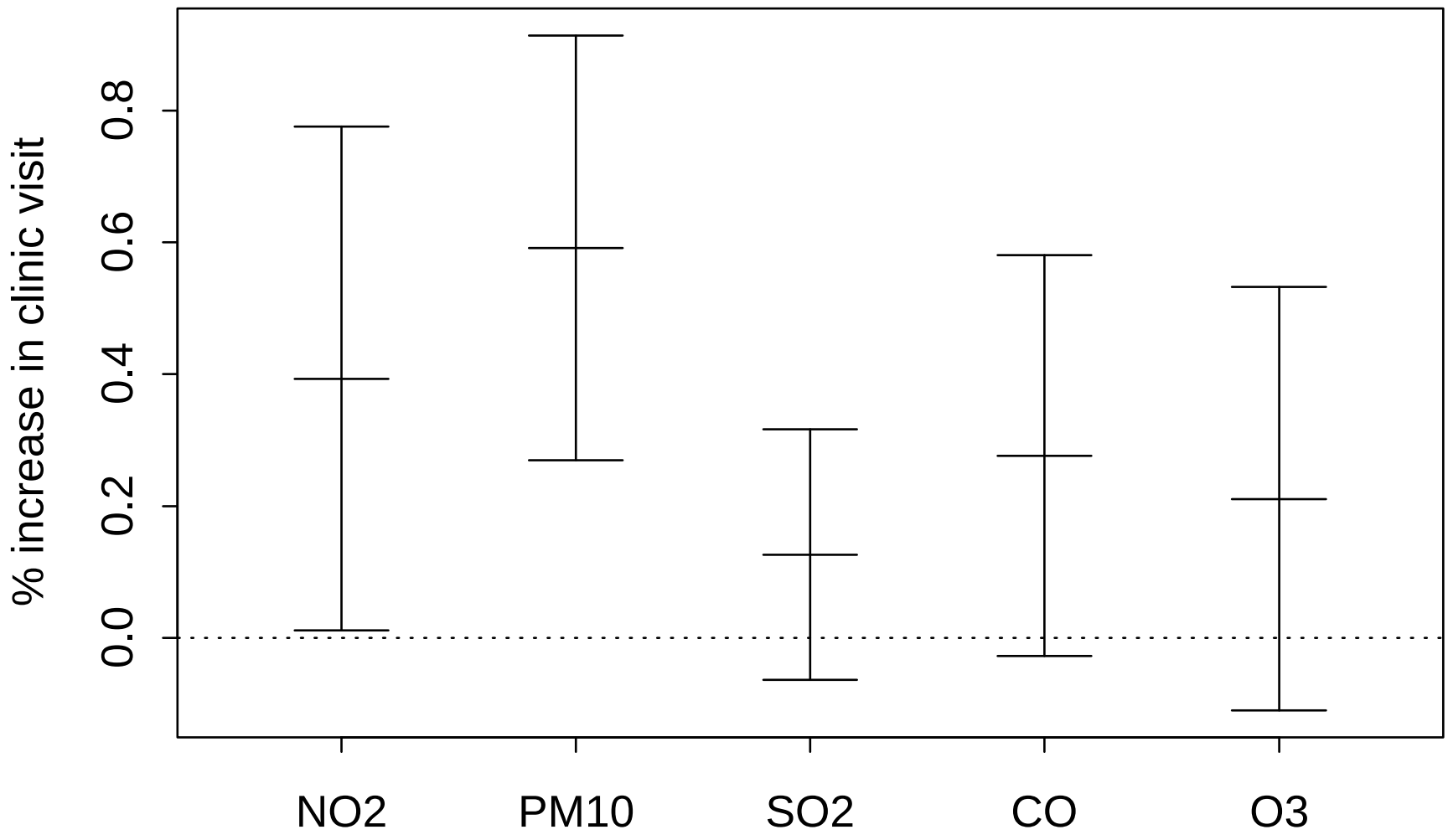

SO2
% increase in clinic visit
3
2
1
0
-1
-2
1
7
12
1997
1998
1999
2000
2001
8
Date


CO
% increase in clinic visit
4
2
0
-2
1
7
12
1
7
12
1
7
12
1
7
12
1
8
12
1997
1998
1999
2000
2001
Date


O3
% increase in clinic visit
2
0
-2
-4
1
7
12
1997
1998
1999
2000
2001
8
Date

Phase IIa results

- Increased risks of clinic visits for 10% increased of average pollution levels for the 5 years 1997-2001


% increase in clinic visit
0.0
0.2
0.4
0.6
0.8
NO2
PM10
SO2
CO
O3

Discussion

- NO_2 and PM_{10} had significant effects on daily clinic visits due to respiratory illness in Taiwan

Discussion

- Most studies modeled a long time series in a big city
- Spatiotemporal models of multiple time series caused computation problems
- The proposed 2 phases modeling is under study

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